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AN ESTIMATION OF REPRODUCTIVE PERFORMANCE OF FARMED ELK (*CERVUSELAPHUS*) IN NORTH AMERICA

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An estimation of reproductive performance of farmed elk (*Cervus elaphus*) in North America.

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Abstract

North American farmed elk producers were surveyed to determine period specific rates of calving, abortion, and dystocia, and to examine the effect of reproduction related mortality on the productivity of farmed elk. The overall calving rate was 86.3% and the calving rate for adult cows was found to be significantly higher than that for heifers. Abortions were seen on 7.6% of farms and the overall abortion rate was approximately 0.6%. Dystocia was experienced in 5.9% of births. Neonatal mortality, summer mortality, weaning mortality, and post-weaning mortality rates were calculated and compared. Failure to produce a live neonate was responsible for 64% of the total reproductive loss and calf mortalities from birth to 1 year of age accounted for 36%. Failure to produce a live neonate had a more significant effect on productivity than did mortalities from birth to 1 year of age, suggesting that reproduction has a greater economic effect on elk farms than neonatal mortality.

Introduction

Until chronic wasting disease (CWD) interrupted trading in elk and elk products, the North American elk industry was in a tremendous growth and expansion phase. In the decade from 1990 to 2000, the number of elk farms in Canada increased from a few hundred to over 1000 (1). In countries like New Zealand, where the cervid farming industry is more mature, reproduction in commercial deer herds has been well examined (2-7) There are few published reports on the reproductive performance of farmed cervids in North America (8). The rapid expansion of the elk industry has provided an opportunity to learn in greater detail about reproduction in commercially farmed elk, permitting veterinarians and other industry professionals to recommend science-based management practices that will reduce reproductive waste and increase productivity. Industry wide measurements of reproductive performance and productivity can provide "benchmark" estimates of reproduction indices. Producers can compare their own herds against these benchmarks to identify areas of deficiency and develop management programs targeted at improving their herd performance. Scientists can target future research efforts towards developing strategies to improve the overall performance of elk farms.

The purpose of this project was to estimate reproductive performance, productivity, and the effect of neonatal mortality on the productivity of farmed elk in Canada and the United States for the 1999-2000 production year.

Materials and methods

In 2000, a survey of 709 North American elk producers was carried out as described by Woodbury et al (9). Producers were randomly selected from a pooled database made from membership lists of national, provincial, state, and regional elk farming associations. The sample reflected the number needed to detect a factor of interest with a herd prevalence of 2% with 95% confidence, if only 50% of the questionnaires were returned.

In addition to information on diseases that caused sickness or mortality on surveyed farms during the study period, survey questions captured data particular to rates and proportions, allowing the age and sex specific measures of reproductive performance and productivity to be estimated for the year 1999 - 2000. Morbidity and mortality statistics have been reported elsewhere (9). Reproductive and productivity rates were based on 1 cohort and were specific to 1 period of the annual production cycle. The calving rate was defined as the percentage of heifer or adult cow elk on the farm that were bred or present at calving time and produced a calf that survived birth and remained alive for at least 24 h. The abortion rate was the percentage of adult and yearling elk cows exposed to breeding that aborted. The dystocia rate was the percentage of all calving females on the farm having difficulty calving. The proportion of dystocias due to twins that were assisted, and dam mortalities resulting from dystocia were also determined as percentages of females having dystocia.

Differences in proportional rates were tested for statistical significance by chi square analysis at a $P< 0.05$ significance level. Summary statistics are mostly provided in tabular form. Crude proportions or percentages were calculated by using the number of animals having the

element of interest, divided by the number of animals at risk from that element during the study period. Mean proportions or percentages are farm level statistics and were calculated by summing the crude proportions described above for each farm responding to the question and then dividing by the number of farms.

Results

Seven hundred and four producers responded to the survey. The overall response rate was 33.9% (239/704), including 34.3% (148/432) from US and 33.5% (91/272) from Canadian elk producers. Respondents provided information about 11943 elk, including 1005 yearling and 3247 adult females, on 239 farms. Not all females were bred and the number of responses to questions on reproduction varied.

Age specific calving rates are shown in Table 1. The overall calving rate for cows and heifers was 86.3%. The calving rate for adult cows was found to be significantly ($P<0.0001$) higher than for heifers.

Abortions were seen on 7.6% of farms. In the group of females exposed to breeding (24/3981), as well as the total females present at calving (25/4168), the abortion rate was ~ 0.6% (6.02 per 1000 animals.).

The results of several questions about dystocia and the percentages of adult and heifer elk reported to have experienced dystocia, dystocia due to twinning, assisted dystocia, or death of the dam due to dystocia are shown in Table 2. There were significantly more dystocias seen in heifer elk, but no difference in the proportion of dystocias due to twinning, needing assistance or resulting in dam death in adults and heifers combined.

Period specific calf mortality rates based on the division of the elk production year into neonatal, summer, weaning, and post weaning periods are shown in Table 3. Neonatal mortality is the proportion of all calves born alive that died before July 1st, summer mortality is the proportion of calves alive at July 1st that died before weaning, weaning mortality is the proportion of elk calves alive at weaning that died within 1 mo of weaning, and post-weaning mortality is

the proportion of calves alive 1 mo post weaning that died by 1 y of age. Also included is the percentage of the total calf mortality from birth to 1 y of age that occurred in each age category. Mortality rate was highest in the neonatal period, decreasing significantly between summer and weaning ($P<0.001$), and rising significantly again in the post weaning period ($P<0.001$).

The relative importance of neonatal mortality to elk producers was assessed by comparing neonatal mortality to lost reproductive opportunities. Total reproduction losses are presented in Table 4 and include all females that were bred but failed to produce a calf, as well as all calf mortalities from birth to 1 y of age. Having at least 1 cow failing to calve was reported by 87.3% of respondents and 71.7% reported at least 1 calf mortality. Failure to calve accounted for 64.0% of reproductive losses and calf mortality was responsible for the remaining 36.0%. These proportions are significantly different ($P<0.0001$)

Discussion

In our opinion, a commonly held belief among elk producers is that 100% calving rates are a frequent occurrence, where all the females of reproductive age in a herd produce a live neonate during a calving season. This study did not support this belief. Overall, only 86.3 % of females produced a live offspring during the study year and there were large differences in reproductive performance between ist partum and adult females. First calf females had calving rates of 79.0%. This was significantly ($P<0.0001$) lower than the 89.6% for adult females. This might be due to the difference in dystocia rates between heifers and cows. The rate of difficult birth in heifers was significantly higher than that of older females, and since dystocia frequently results in calf mortality, heifers would therefore also have a higher dystocia-associated neonatal death loss. The lower heifer calving rate might also be related to conception rates. There is a threshold weight below which elk heifers generally do not conceive. An unknown proportion of the survey heifer population may have been below this threshold weight, resulting in poorer conception rates.

The overall abortion rate of 0.6% is a relatively low figure and may underestimate the true rate. Since farmed elk are only semidomesticated and elk producers are probably less intimate with their stock than producers of other domesticated hoof stock, elk producers may not have observed all abortions that occurred within their herds. Fetal absorption may also account for the failure to calve in some animals but the causes of fetal absorption in elk have not been described and the relative importance of this event is unknown.

Dystocia was a fairly common experience on elk farms (Table 2). Close to half (44.6%)

of farms experienced at least 1 dystocia during the 1 year period of the study. Similar to New Zealand red deer and confirming the conventional wisdom among Canadian elk producers, the rate of dystocia for heifers was much higher than that for adult females (4). Dystocia was rarely associated with twins, with only 5.9% of all dystocias being related to twinning. Overly fat females are considered at risk from dystocia (10) and a New Zealand red deer study suggested that cow condition was primarily responsible or a contributory factor in as much as half of the observed cases in a single season (11). Freidel and Hudson (8) reported a 62.3 % neonatal mortality rate resulting from dystocia in western Canada. This was not supported by our study, where only 8.9% of producer reported neonatal mortality was due to dystocia.

Even though elk producers were able to provide assistance to a large proportion of their elk with dystocia (83.8%), the mortality rate among females with dystocia was relatively high (9.1%). This may reflect the stage at which assistance was provided. Elk cows are not routinely observed giving birth, and even if difficulties are encountered, a relatively long period may pass before the animal can be successfully caught and restrained, leading to exhaustion of the dam and other post partum complications resulting from late intervention and handling (10).

When calculated over 4 different time periods from birth to 1 year of age (Table 3), neonatal mortalities were highest during the 1st month after birth compared to the summer months, at weaning, and after weaning to 1 year of age. Pople et al (12) found that 36.9% of neonatal mortalities during that period were from infectious disease. Our own survey of pathology records shows that diarrhea, septicemia, and pneumonia alone were responsible for 42.4% of mortalities in that age group (9). Other studies have indicated that management related factors, such as mismothering and calf abandonment, are responsible for a substantial amount of

neonatal death (3,12). Producers in our survey attributed 9.7% of calf morbidity and 13.6% of mortality to dam agalactia and, or calf abandonment (9). However, deaths due to dehydration, emaciation, and starvation, but misclassified by producers as "unknown", may have, in fact, resulted indirectly from factors such as maternal inadequacy. This would result in an underestimation of the importance of environmental- and management-related deaths in neonatal elk in relation to infectious disease.

The increase in calf mortality rates observed during the period from 1 mo after weaning to 1 y of age may not be a result of a higher true rate of mortality but, rather, it may be a product of this time period being of longer duration than the previous 2.

Diarrhea, septicemia, and pneumonia are common syndromes associated with neonatal mortality in other farmed species, as well as elk. The syndromes are precipitated by a collage of risk factors including infectious agents, nutrition, weather, genetics, behavioral characteristics of the dam, and management conditions (2). The information about risk factors for these diseases in other farmed species should be made to establish causal associations between the risk factors and disease in elk.

The relative importance of neonatal mortality to elk producers was assessed by comparing neonatal mortality with lost reproductive opportunities (Table 4). On each farm, the number of neonates that died from birth to 1 y of age was added to the number of females failing to produce a live neonate, providing a statistic that represents the total reproductive loss on the farm. Failing to produce a live neonate was responsible for 64% of the total reproductive loss, while neonatal mortalities from birth to 1 y of age accounted for 36%. The difference was highly statistically significant and suggests that reproduction, as defined by the proportion of females producing a

154 live neonate, has a greater economic effect on elk farms than neonatal mortality.

155 In real terms, successful reproduction has a strong influence on the number of elk
156 yearlings produced on elk farms. Research aimed at improving the reproductive performance of
157 farmed elk would be cost effective and beneficial to the industry. These efforts might begin by
158 educating elk producers about the importance of reproduction, since many of them are under the
159 mistaken impression that reproduction is not an important factor to the economic health of their
160 farms. Elk producers should be encouraged to keep annual records of their herd's reproductive
161 performance. This would make them aware of their herd's true reproductive performance and
162 allow them to identify and cull females with suboptimal reproductive performance. Prospective
163 studies aimed at more clearly establishing benchmarks for reproductive performance of
164 commercially farmed elk, similar to those of Audigé et al. in red deer in New Zealand (2-5),
165 should be conducted over extended periods of time in North America.

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200 **Tables**

201 Table 1. Calving rate[a] of elk heifers and adult elk cows for the production year 1999 - 2000.

	Adult cows	Heifers	Cows and heifers
Number of farms	235	185	240
Number of cows	3242	926	4168
Number of calves	2905[b]	732[b]	3637
Crude calving %	89.6	79	87.3
Mean calving %	92.7	82.5	90.6
Range (%)	0.0-100.0	33.3-100.0	0.0-100.0

a - Calving rate is the percentage of heifer and adult cow elk that were present at calving time and produced a calf that survived birth and was alive for at least 24 hours.

b - statistically significant difference between groups ($P<0.0001$)

Table 2. Percentages of adult and heifer elk reported to have experienced dystocia, dystocia due to twinning, assisted dystocia[a], or death due to dystocia for the production year 1999 - 2000.

	Adult cows	Heifers	Both
Number of farms	235	173	240
Number of farms with dystocia	82	50	107
Percentage of farms with dystocia	34.9	28.9	44.6
Number of females	2968	766	3734
Number of dystocias	147[b]	75[b]	222
Crude % of dystocia	5.0	9.8	5.9
Mean % of dystocia	5.3	9.9	6.5
Range (%)	0.0-66.7	0.0-100.0	0.0-66.7
Dystocias due to twins			
Number of dystocias due to twins	8	1	9
Crude % of dystocias due to twins	6.8	1.3	4.1
Mean % of dystocias due to twins	4.9	1.2	3.2
Range of dystocias due to twins (%)	0.0-100.0	0.0-60.0	0.0-100.0
Assisted dystocias			
Number of assisted dystocias	125	61	186
Crude % of assisted dystocias	85.0	81.3	83.8
Mean % of assisted dystocias	82.6	77.3	79.5
Range of assisted dystocias (%)	0.0-100.0	0.0-100.0	0.0-100.0
Dam mortality due to dystocia			
Dam mortalities due to dystocia	14	5	19
Crude % of dam mortality due to dystocia	9.5	6.7	8.6
Mean % of dam mortality due to dystocia	12.0	10.0	11.7
Range of dam mortality due to dystocia (%)	0.0-100.0	0.0-100.0	0.0-100.0

a - birth assisted by interference from the producer or a veterinarian.

b - statistically significant difference between groups ($P<0.05$)

Table 3. Elk neonatal, summer, weaning and post weaning period calf mortality rates for the production year 1999 - 2000.

	Neonatal[a]	Summer[b]	Weaning[c]	Post-weaning[d]
Number of farms	240	240	240	240
Number of calves at risk	3744	3559	3508	3469
Number of mortalities	185	51	12	51
Crude % mortality	4.9 [e,f]	1.4 [e]	0.3 [e,f]	1.5 [f]
Mean % mortality	9.1	1.3	0.3	1.2
Range (%)	0.0-66.7	0.0-28.6	0.0-25.0	0.0-100.0
% of total calf mortality	61.9	17.1	3.9	17.1

a. The proportion of all calves born alive that died before July 1st.

b. The proportion of calves alive at July 1st that died before weaning.

c. The proportion of elk calves alive at weaning that died within 1 mo of weaning.

d. The proportion of calves alive 1 mo post weaning that died by 1 y of age.

e, f - statistically significant difference between groups ($P < 0.05$)

Table 4. The percentage of total reproduction losses[a] for elk that was due to either failure of females to deliver a live calf or calf mortality in the production year 1999 - 2000.

	Factor	
	Failure to calve	**Calf mortality**
Number of farms	187	187
Percent of all farms reporting factor	87.3	71.7
Number of does failing to produce or calves dead	531	299
Crude % of reproduction loss due to factor	64[b]	36[b]
Mean % of reproduction loss due to factor	63.2	36.9
Median % of reproduction loss due to factor	66.7	33.3
Range of % of reproduction loss due to factor	0.0-100.0	0.0-100.0

a - Reproduction losses are for the period between breeding and resulting calves reaching one year of age. Total reproduction loss includes all females that were bred but failed to produce a calf, as well as all calf mortalities from birth to 1 y of age (females n = 830).

b - statistically significant difference between groups ($P<0.0001$)

A retrospective study of the causes of morbidity and mortality in farmed elk (*Cervus elaphus*)

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Abstract

A survey of North American farmed elk producers was performed to determine the causes of sickness and mortality in farmed elk and to estimate mortality rates. Records over a 10-year period from 8 North American veterinary diagnostic pathology laboratories were also examined and summarized. The primary diagnosis for each record was used to classify diseases into categories such as parasitic, infectious, toxicological, and neoplastic. Nonspecific trauma was the most frequently reported known cause of mortality in both sexes and all age classes by elk producers. Ranked on perceived economic importance, producers cited trauma, chronic wasting disease, calf scours, dystocia, pneumonia, winter tick, tuberculosis, and grain overload. One-year mortality rates for adults and yearlings were 2.6% and 2.7%, respectively. Mortality rates for male and female adult animals were 2.4% and 2.7%, respectively. In general, the major findings of the pathology survey matched reported causes for mortality provided by elk producers.

Introduction

In the decade from 1990 to 2000, the number of elk farms in Canada increased from a few hundred to over 1000 (1). Previous disease surveys involved relatively few diagnostic reports from relatively few elk farms (2,3). Expansion of the elk industry provided an opportunity to learn in greater detail about the causes of morbidity and mortality in farmed elk. More detailed knowledge will permit veterinarians and other industry professionals to make science-based recommendations for disease prevention activities and management changes that will improve animal welfare and increase productivity in the elk industry. Industry wide measurements of morbidity and mortality rates provide "benchmark" estimates of these indices. Farmers can compare their own herds against these benchmarks to identify areas of deficiency and develop management programs targeted at improving their herd performance. Scientists can target research efforts towards developing strategies to improve the overall performance of cervid farms.

The purpose of this project was to report the causes of sickness and mortality in farmed elk in Canada and the United States over a 10-year period and to estimate the age and sex specific mortality rates for the 1999-2000 production year.

Materials and methods

Producer survey

A set of 35 questions designed to gather observational data about mortality rates and morbidity and reproduction parameters in farmed elk was pretested at 2 industry conventions. Prototype questionnaires and interviews were given to convention participants to ensure that the questions were easily understood and that producers could provide the data requested of them. The survey was then mailed to North American elk producers. To ensure confidentiality, only the name of the state or province where respondents farmed elk was requested.

A random sample of 709 elk producers was selected from a pooled database made from membership lists of national, provincial, state, and regional elk farming associations. After removing duplicate names, the sampling frame contained 1694 producers, who were then grouped by nationality and sampled in proportion to the number of Canadian and US producers in the sampling frame. The number of producers sampled reflected the number needed to detect a disease with a herd prevalence of 2% with 95% confidence, if only 50% of the questionnaires were returned. Producer names were sequentially numbered as they appeared in the database; computer generated randomized numbers were then used to select the sample.

The format of the questionnaire followed Dillman's recommendations for maximum response to postal questionnaires (4). To maximize the response rate, respondents were made eligible for a lottery draw for 5l of an anthelmintic (Cydectin ,Wyeth Animal Health, Guelph, Ontario). Included with the questionnaire was an explanatory letter introducing the survey and emphasizing the benefits of the study, a lottery entry form, and a stamped self addressed return

envelope. Postcard reminders were sent out to all producers 2 and 4 wk later. After approximately 6 wk, a 2nd identical questionnaire package was mailed to nonresponders and postcard reminders were mailed to them 2 and 4 wk later.

To ensure confidentiality, responses were immediately coded after receipt and entered into a database (Microsoft Access, Microsoft Corporation, California, USA) database with no association between answers and respondents. Database entries were checked twice against questionnaires for their accuracy, and the internal validity of the database was assessed by comparing the answers to check questions. Database errors resulting from incorrect data entry were corrected in the database.

The at-risk study population was stratified according to age and sex, and mortality rates were calculated for each age and sex class over the 1-year period of the study. Producers were asked to name diseases that caused sickness or mortality on their farms during and before the period of the study. Morbidity and mortality rates were calculated for adults and yearlings over the 1999-2000 production year and expressed as percentages. Cohort specific morbidity and mortality rates for calves born in 2000 were not based on 1-year periods; rather they were based on specific time periods of risk. For example, neonatal mortality rates were calculated as a proportion of those calves born during the 2000 calving year that died within 1 mo after birth.

Assuming that most trauma arises through animal handling, we attempted to determine the likelihood of an injury resulting from any single handling event, and producers were asked to provide information about their most recent handling session; for example, weaning or tuberculosis testing.

Differences in proportional rates were tested for statistical significance by chi square analysis at a 0.05 significance level. Summary statistics are mostly provided in tabular form. Crude proportions or percentages were calculated by using the number of animals having the element of interest, divided by the number of animals at risk from that element during the study period. Mean proportions or percentages are farm level statistics, that were calculated by summing the crude proportions described above for each farm responding to the question and then dividing by the number of farms.

Pathology laboratory survey

Forty-two veterinary diagnostic pathology laboratories in the United States and Canada were contacted and asked to participate in the study. Of those laboratories willing to participate, 8 were selected for inclusion, based on the number of elk submissions they received over the period from 1990 to 2000 and on their ability to extract useful information from their records. These included laboratories form Alberta, British Columbia, Colorado, Minnesota, North Dakota, Saskatchewan, and South Dakota.

Submissions that included more than 1 dead elk were entered as a single record and each submission was considered 1 disease report without regard to size. Data were extracted from each record and coded into a database (Microsoft Access, Microsoft Corporation). To maintain client confidentiality, submissions for pathology examination were identified only by an ID number. Keystone information stored for each record included submission date, age, sex, species, and primary cause of mortality. The primary diagnosis for each record was used to classify records into disease categories, such as parasitic, infectious, toxicological, neoplastic, etc. In

addition, 3 pathology diagnoses were recorded for each submission, based on the anatomical location, the pathological change, and the etiology associated with each lesion. Database entries were checked twice against the original records for the accuracy of each entry.

Results

Producer survey

Seven hundred and nine producers responded to the survey . Five questionnaires contained unreliable information and were removed from the study. The overall producer survey response rate was 33.9% (239/704), including 34.3% (148/432) of US and 33.5% (91/272) of Canadian elk producers. The distribution of Canadian respondents was skewed heavily towards the western provinces, with 96% of the responses divided between Alberta (44%) and Saskatchewan (51.8%). The Saskatchewan industry contributed 55.5 % (3021/5446) of the total animals in the Canadian database, Alberta contributed 40% (2180/5446). South Dakota had the highest response (54.5%) from a US state, followed by Wisconsin (54.5%) and Kansas (46.2%). However, Minnesota contributed survey information on the most US animals (1393/6497 or 21.4%), followed by Wisconsin (882/6497 or 13.6%), Colorado (759/6497 or 11.7%), and Iowa (656/6497 or 10.1%).

Overall, survey respondents provided information about 11943 elk. Of the total number, 3748 (31.4%) were live calves, 2116 (17.7%) were yearlings, and 6079 (50.9%) were adult animals. There were 1111 (52.5%) male and 1005 (47.5%) female yearlings, and 2832 (46.6%) male and 3247 (53.4%) female adults.

Producers reported 360 mortalities in elk of all ages (Table 1). Three hundred and five mortalities (84.7%) were attributed to a cause, the remainder were listed as unknown. In 60% of the reports, a veterinarian had been consulted for diagnosis or treatment. One-year mortality rates were similar for adult and yearling elk, 2.6% and 2.7%, respectively. Mortality rates for male and female adult animals were also similar, 2.4% and 2.7%, respectively. The rate for yearling males (3.3%) appeared to be higher than that of yearling females (2.0%) but the difference was not statistically significant (P=0.10).

There were 46 producer-described causes of morbidity, mortality, or both, for elk of all ages. However, 38 of these causes were reported fewer than 5 times over the study period and are grouped in Table 1 as "other" disease. These "other" diseases accounted for 36.7% of the disease reports, which included 40.2% of the morbidity, and 23.3% of the mortalities. Unspecified parasitism (15.3%) and pinkeye (8.7%) accounted for most of the morbidity from this "other" group. Overall, the most frequently reported problem was unspecified trauma, comprising 20.5% of reports. Trauma was usually fatal, resulting in death in 46 animals and recoverable injury in only 9 animals.

Age specific information about the causes of elk mortality is provided in Table 2. Unspecified trauma was the most frequently reported health problem in all age classes of elk and was the 2nd most frequent known cause of mortality in yearlings and adults. Handling related injury and mortality proportions for elk calves, yearlings, and adults are provided in Table 3. Proportions are expressed as the percent of all elk that were injured or died following the last handling event recalled by the producer. Yearling bulls suffered proportionately more injuries

(2.1%) than did the other age and sex classes, but the difference was significant only when compared with adult cows (P=0.003) and calves (P=0.008).

Neonatal mortality was calculated over 4 different time periods from birth to 1 y of age: Neonatal mortality (4.9%) was the proportion of all calves born alive that died before July 1st; summer mortality (1.4%) was the proportion of calves alive at July 1st that died before weaning; weaning mortality (0.3%) was the proportion of elk calves alive at weaning that died within 1 mo of weaning; and post-weaning mortality was the proportion of calves alive 1 mo post weaning that died by 1 y of age (1.2%). Each period was significantly different from the other (P<0.0001), except for the summer and post weaning periods (P=0.90).

Two hundred and forty respondents answered the question: Have you ever had 1 of the following diseases in your elk? Of the 17 disease conditions presented in the question, winter tick was most commonly mentioned (23.8%), followed by calf scours (22.1%), grain overload (14.2%), and pneumonia (12.1%). Other parasitic diseases reported were lungworm (7.1%), liver fluke (6.7%), and meningeal worm (1.3%). Pinkeye was mentioned by 4.6% of respondents and 4.6% claimed that they had experienced bloat on their farm.

From a list of 21 diseases, respondents were asked to choose a) the single disease they thought was most economically important to individual elk farming operations and b) the one they considered the most economically important to the elk industry. Diseases were ranked according to the number of respondents selecting each disease as most important. With regard to individual operations, trauma (nonspecific) was cited most often from 142 responses, followed in descending order of frequency by chronic wasting disease (CWD), calf scours, dystocia, pneumonia, and winter tick. Tuberculosis and grain overload were ranked 7th and intestinal

parasites, 8th. Liver fluke was 9th and capture myopathy, lungworm, and nutritional disease were mentioned 10th most often as being most important to individual farms. Another 3 diseases shared the remaining votes equally.

One hundred and ninety respondents ranked diseases according to their importance to the overall industry. Chronic wasting disease was mentioned most often, followed by tuberculosis, Johne's disease, calf scours, and intestinal parasitism in that order. Capture myopathy, liver fluke, and winter tick were the 6th most frequently mentioned diseases. The remainder of 1st place votes were divided equally among babesiosis, blackleg, brucellosis, bluetongue, and dystocia.

Pathology laboratory survey

The pathology laboratory survey yielded 1077 submissions. There were 314 (29.1%) female and 258 (24%) male elk submitted, and there was 501 (46.9%) submissions where the sex was not recorded. Twenty-nine (2.7%) submissions were less than term fetuses and 49 (4.5%) were animals less than 24 h old. One hundred and seventy-five (16.3%) submissions were older than 24 h but less than 30 d of age. There were 145 submissions (13.5%) from animals > 30 d but <1 y, and 473 submissions (44.1%) from animals >1 y; 206 submissions (19.1%) were of unknown age.

In general, the major findings of the pathology survey matched reported causes for mortality provided by elk producers. Primary diagnoses of pathology laboratory submissions for all ages of elk are summarized in Table 4. There were 94 diagnoses identified in the data set, but many causes had only 1 or 2 submissions, so primary diagnoses with less than 10 submissions

are identified as "other." The most common nonspecific primary diagnosis for the cause of death was either no diagnosis or emaciation. Emaciation was listed as a cause of mortality when the carcass was emaciated, but no cause for the emaciation could be found by the pathologist. The 2nd most common cause of mortality in the pathology records was trauma. Unknown and trauma were also the 2 most common causes of mortality reported by elk producers.

The primary laboratory diagnoses by age group are summarized in Table 5. Among elk aged <30 d there were 39 different diagnoses identified in the data set, but diagnoses with fewer than 3 submissions were reported as "other." The most common primary diagnoses were enteritis (21.2%), septicemia (12.8%), and pneumonia (8.0%). Causes of enteritis in elk included *Escherichia coli*, *Rotavirus*, *Nematodirus* spp., *Clostridium perfringens* and cryptosporidia infections. The most important reported cause of septicemia was *E. coli* infection. Other, less important causes included infection by *Clostridium* spp., *Salmonella* spp and *Arcanobacterium pyogenes*. The most important reported cause of pneumonia was infection by *A. pyogenes*, followed by *Pasteurella* spp., *E.coli*, *Aspergillus* spp., and *Mycobacterium* spp.

There were 43 different diagnoses identified for elk between 30 and 365 d of age. Diagnoses with fewer than 3 submissions were reported as "other." The exceptions were listeriosis, coccidiosis, and copper deficiency, which were included for their relevance to other species. Pneumonia was the most common primary diagnosis (13.9%) and unspecified trauma was the 2nd (9.0%). Other important primary diagnoses were unspecified parasitism (6.9%) and septicemia (4.9%).

The data set for elk >1 y contained 59 diagnoses, but those associated with less than 5 submissions were reported as "other." The most common primary diagnoses of elk pathology

198 submissions in this age group were trauma (16.2%), followed by pneumonia (7.4%). Other
199 important primary diagnoses for elk >1 y were kidney disease (6.5%), abscesses (4.0%), liver
200 disease (3.4%), and enteritis (2.9%).

201 Of the 133 morphologic diagnoses for mortalities with lesions in the respiratory tract, the
202 most common was pneumonia (88/133 or 66.2%). Most frequently the etiology for the
203 pneumonia was "unknown" (36/88 or 40.9%). Of the known etiologies, *A. pyogenes* was the
204 most common (17%) , followed by *Pasteurella* spp. (6.8%). Pulmonary edema was an important
205 primary diagnosis of respiratory tract lesions, but in none of these submissions was an etiology
206 reported.

207 The most common morphologic diagnosis of 186 elk pathology submissions with
208 gastrointestinal lesions was enteritis (81/186 or 43.6%). The most common etiological agents
209 associated with enteritis were *E. coli* (20/81 or 24.7%), Rotavirus (7.4%) and *Clostridia* spp.
210 (8.6%). Parasitic enteritis etiologies included coccidia, *Trichostrongylus* sp., *Strongyloides* sp.,
211 *Nematodirus* sp., *Haemonchus* sp., and *Trichurus* sp. The 2nd most common etiology associated
212 with gastrointestinal lesions was grain overload (9.7%). Johne's disease was also important in
213 causing morbidity in elk (7.0%).

214 The most common parasites reported in 75 submissions where the primary cause of
215 mortality was parasitism were liver flukes (26/75 or 34.7%), including *F. magna* and *D.*
216 *dendriticum*. Other parasites reported included coccidia (5/75), *Trichostrongylus* sp. (4/75),
217 *Trichuris* sp.(3/75), *Babesia* sp.(2/75), *Nematodirus* sp.(2/75), tapeworm (3/75), *Haemonchus*
218 sp.(1/75), *Sarcocystis* sp.(1/75), *Cephenemyia* sp.(1/75), and ticks (1/75).

Encephalitis was the most common (17/45 or 37.8%) morphologic diagnosis for 45 pathology submissions showing central nervous system lesions, followed by meningitis (12/45 or 26.7%). Etiologies were often not reported for encephalitis (12/45), but those that were included infection by *E. coli* and *A. pyogenes*, and parasitism by *Elaeophora schneiderii*. Causes of meningitis were likewise infrequently recorded, but *E.coli* (4/12) and *P. multocida* (1/12) were found. Other important primary diagnoses associated with central nervous system lesions were locoweed poisoning (8/45) and spongiform encephalopathy (3/45).

Of the 280 primary diagnoses associated with infectious disease, septicemia (55/280 or 19.6%), followed by pneumonia (43/280 or 15.4%), enteritis (45/280 or 16.1%), and abscesses (38/280 or 13.6%) were the most common. Etiologies associated with septicemia were largely unrecorded (24/550) but included most commonly *E. coli* (17/55), followed by *Clostridium* spp. (4/55), *A. pyogenes* (2/55), *Salmonella* spp. (2/55), and *Listeria* spp. (2/55). Pneumonia was most commonly associated with *A. pyogenes*, (15/43), unidentified bacteria (7/43), *Pasteurella* spp., *Aspergillis* spp.(6/43), *Mycobacterium* spp. (2/43), *Streptococcus* spp. (1/43), *Aeromonas hydrophilia* (1/43), and *E. coli* (1/43). Abscesses were mostly not attributed an etiology (24/38). Those that were, were attributed most commonly to *A. pyogenes* (9/38), followed by unspecified bacteria and fungal agents. Infectious enteritis was most frequently associated with *E. coli* (20/45), followed by Rotavirus (7/45), *C. perfringens* (5/45), and unidentified viruses (6/45) or bacteria (5/45).

238 **Discussion**

239 *Producer Survey*

240 The response rate and the proportional numbers of elk represented from Alberta and
241 Saskatchewan accurately reflect the distribution of farmed elk in Canada in 1999-2000. Canadian
242 inventory records for the year 2000 show that Alberta had 47.9% of Canada's elk herd and
243 Saskatchewan had 41.9% (1). At 55% of the surveyed Canadian elk, elk in Saskatchewan are
244 somewhat over represented, but in the authors' opinion, management techniques and feeding
245 practices do not differ appreciably between the 2 provinces. The US samples were also selected
246 proportionately, but they can be assumed to reflect a wider range of geographic influences on
247 morbidity and mortality, such as climate and feed type, than did the Canadian samples. However,
248 major industry problems, such as handling related trauma, are largely independent of regional
249 influences on the incidence of infectious disease, such as climate.

250 The cause of most mortality was unknown or due to unspecified trauma (Table 1).
251 Similar findings regarding the importance of trauma as a cause of mortality have been reported
252 elsewhere (3). However, in our survey, trauma was associated with the most individual
253 mortalities only in calves (Table 2). Aside from tuberculosis, the cause of most producer reported
254 mortalities was unknown. There may have been several reasons why producers did not know the
255 cause of their elk mortalities, including failing to employ a veterinarian to perform a postmortem
256 diagnosis on dead animals. The use of veterinarians was highly variable among individual elk
257 producers but veterinarians were consulted for 60% of disease occurrences. Nine outbreaks of
258 tuberculosis involving 118 mortalities were reported, making this disease the primary cause of
259 producer reported individual elk mortality in North America in 2000. This finding was not

supported by our pathology record survey results, although this may be because submissions that included more than 1 dead elk were entered as a single record into the laboratory database and each submission was considered 1 disease incident without regard to size.

In our producer survey, adult tuberculosis accounts for almost 10 times as many mortalities as trauma. Interestingly, tuberculosis was also reported to have caused the most yearling deaths. It is uncertain whether deaths attributed by producers to tuberculosis were actually caused by disease or were, in fact, postmortem findings subsequent to tuberculosis control slaughter programs. Although tuberculosis is certainly an important cause of disease in elk, it tends to cluster within herds and in some years, it may be infrequently reported, depending on surveillance activity.

Age specific injury and mortality rates indicate that yearling bulls are most at risk from injury during handling episodes and injure themselves more than twice as often as yearling heifers (Table 3). However these injuries were apparently not as likely to be fatal and males were not more likely to die as a result of handling than females. No handling fatalities were reported for yearling males, which is perhaps surprising given their disposition to panic and flight when handled. Recall that overall mortality rates for yearling males (3.3%) is higher than for any other age or sex class, and although in this study the difference is not statistically significant, it makes empirical sense to those who handle elk frequently.

Since trauma associated with handling farmed elk was identified as an important known cause of mortality, research aimed at improving handling systems would be beneficial. Improved understanding of elk behavior in both a confined setting and during handling or processing

activities is needed. Basic principles for handling elk should be developed, so that paddocks and handling facilities that are less likely to cause injuries could be designed.

Neonatal mortalities were highest during the 1st month after birth compared to the summer months, at weaning, and after weaning to 1 y of age ($P<0.0001$). Pople et al (5) found that 36.9% of neonatal mortalities during the 1st month of life were from infectious disease. Our survey of laboratory records shows that diarrhea, septicemia, and pneumonia alone were responsible for 42.4% of mortalities in that age group (Table 5). The rates dropped over the summer and at weaning but increased again for the period from 1 mo after weaning to 1 y of age. This increase may not have resulted from a truly higher rate but rather because this period was longer than the previous 2.

Diarrhea, septicemia, and pneumonia are common disease syndromes associated with neonatal mortality in other farmed species, as well as elk. The syndromes are precipitated by a collage of risk factors including infectious agents, nutrition, weather, genetics, behavioral characteristics of the dam, and management conditions.The information about risk factors for these diseases in other farmed species, should be used to establish causal associations between the risk factors and disease syndromes in elk. For example, previous studies in deer have identified behavioral characteristics of the dam, such as mismothering and calf abandonment, as important to neonatal mortality (5,6). Information about dehydration, starvation and emaciation problems indirectly related to inadequate maternal care was not captured in our survey. Dam agalactia or calf abandonment was held responsible for 9.7% of calf morbidity and 13.6% of calf mortality (Table 2), but we suspect that elk calves dying indirectly from factors like calf

abandonment may have been misclassified as "unknown cause," thereby underestimating the importance of management-related factors in fawn mortality.

To compare the overall mortality experienced between farmed cervids, a 1 y age and sex standardized mortality rate for elk, white-tailed, fallow, and red deer was calculated from the results of similar surveys by the authors. The rates of mortality for each age and sex class of each species was standardized against the combined population of elk and white-tailed, red, and fallow deer. Although the populations of the 4 species in this study had slightly different age and sex structures, white-tailed deer had the highest mortality rate at 13.9%. It was 5.2 times higher than red deer (2.7%), 2.7 times higher than fallow deer (5.2%), and 3.0 times higher than elk (4.6%). This standardized mortality rate for elk is larger than the 2.6% crude mortality rate reported for adult elk in our study and should only be used to compare mortality among species.

Producer derived information about on-farm morbidity focused largely on parasitic disease. Winter tick (*Dermacentor albipictus*) was identified by a large proportion of elk producers and presumably it caused large problems. The life cycle of this one-host tick is such that most of the larval developmental stages occur on the animal (7). Not all stages are feeding at the time of systemic treatment with avermectins and not all stages are susceptible to currently available acaricides. These factors and practical considerations, such as application of water-based treatments at sub zero temperatures, can make effective treatment difficult. Environmental management of the parasite may be the best alternative to current treatments (7).

Other diseases mentioned by producers, such as grain overload, are management-based. The practice of strategic feed supplementation to optimize performance in antler growth or reproduction and lactation can be problematic if producers do not understand the hierarchical

nature of elk herd structure. The most socially aggressive animals are often at risk from supplementation practices, unless consideration is given to factors such as adequate feeder space, feeding frequency, and gradual onset of supplementation.

Producer ranking of diseases important to themselves and the elk industry demonstrated an awareness of existing problems, as well as potential disease threats. By acknowledging that handling trauma is a current problem on their farms, producers have taken the first step towards developing welfare friendly handling and restraint techniques and systems. Naming CWD, calf scours, pneumonia, and parasitism as important diseases accurately reflects the general disease syndromes found in North American pathology surveys (1,2,8). Producers accurately predicted that CWD, bovine tuberculosis, and Johne's disease (*Mycobacterium paratuberculosis* infection) would be problems to the industry. The surveys were conducted in 2000, prior to the discovery of widespread CWD in wild cervids, and before an appreciation of the magnitude of mycobacterial disease in wild cervids in Michigan (9) and Manitoba (10).

Pathology laboratory survey

An attempt was made to include only those records which could be determined to have originated from farmed elk. Although many of the laboratories did not provide information clearly stating that submissions originated from farmed elk, there was often information within the body of the record, that allowed submissions to be classified as to their origin. Records of elk heads submitted from hunter-killed elk for CWD testing, as well as from those submitted from clients who were fish and game officers or from those that contained information indicating that

a elk was shot with a rifle, were excluded from the database. It was not possible, however, to determine the origin of all submissions and the database must be considered to contain some submissions from free ranging elk.

Submissions comprising more than 1 dead elk were entered as 1 disease incident because we felt that farmers and veterinarians would be reluctant to submit all dead elk from an outbreak for laboratory analysis due to the cost of laboratory diagnosis. Rather, they would submit only as many mortalities as they felt were necessary to firmly establish a cause of death. Therefore, the number of elk submitted in each disease incident was considered to be a poor estimate of the mortality rate in an outbreak. Any inferences about the relative importance of specific diseases obtained from this portion of the study must relate to the number of disease incidents, rather than to overall mortality associated with the disease.

The most common non-specific cause of death was either no diagnosis or emaciation. To some extent, the ability of a diagnostic pathologist to determine cause of death is dictated by the adequacy of case history information and the financial resources available to pursue laboratory investigations. One could speculate that improved case history submissions and more laboratory testing might have reclassified many of the emaciation cases.

Analysis of laboratory reported calf mortality (Table 5) suggests that disease, for example, enteritis and septicemia, rather than management or other factors, such as mismothering, were responsible for most mortalities in calves <30 d of age. As noted elsewhere in this discussion, some studies in deer have identified environmental or management related factors such as mismothering and abandonment resulting in a diagnosis of dehydration and emaciation as being at least as important as disease in causing neonatal deaths (5,6). Data were

366 accumulated from summary reports provided by participating laboratories rather than close
367 examination of case report contents. Because of this, we feel that information helpful in
368 identifying a lack of maternal care or environmental causes of morbidity and mortality was not
369 collected, leading to a default diagnosis of unknown cause of death. The effect of this would be
370 the relative overreporting of disease issues and underreporting of management related issues in
371 neonatal mortality.

372 No effort was made to separate mortality diagnoses by pathology laboratory, perhaps
373 giving some indication of regional importance of diseases, such as pneumonia. It is now
374 understood that early cases of CWD were misclassified because the presenting signs were that of
375 an aspiration pneumonia or nonspecific emaciation. Impaired vagus nerve function in CWD
376 results in swallowing problems, often leading to secondary aspiration pneumonia (11).
377 Histological examination of brain is time consuming and costly, so animals classified as
378 pneumonia or nonspecific emaciation may have, in fact, been CWD cases, but there is no
379 practical way to confirm this.

380 In summary, the highest mortality rates in farmed elk occurred in the neonatal period
381 from birth to 1 mo of age, and resulted from a variety of conditions precipitated by risk factors
382 including environment, management, and nutrition. Epidemiological research targeted at
383 determining causally associated risk factors could help to reduce the incidence of these neonatal
384 diseases. Elk farm productivity is also strongly influenced by post weaning mortality, a large
385 proportion of which is due to handling associated trauma and, therefore, preventable. Improved
386 facilities and the use of appropriate handling practices would be of great benefit.

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Tables

Table 1. Single year[a] producer-reported causes of morbidity and mortality for elk of all ages.

Disease Name	No. of Sick	No. of Dead	No. of Reports	Vet [b]
Unspecified trauma	9	46	43	13
Unknown	45	55	35	25
Dystocia	5	13	12	7
Pneumonia	15	14	13	13
Tuberculosis	22	118	9	9
Calf scours	19	13	8	5
Dam agalactia	19	13	8	5
Kidney failure	3	4	5	5
Other (38)	91	84	77	44
Total	**229**	**360**	**210**	**126**

a - May 1, 1999 - April 30, 2000

b - The number of incidents in which a veterinarian was consulted for diagnosis or treatment strategies.

Table 2. Single year[a] producer-reported causes of morbidity and mortality for elk by age group.

Disease Name	No. of sick	No. of dead	No. of reports	Vet [b]
Calves				
Unknown	22	36	14	13
Unspecified trauma	2	22	18	5
Dam agalactia/ abandoned calf	14	20	10	0
Calf scours	23	16	9	5
Pneumonia	13	9	9	9
Dystocia	3	9	8	3
Stillborn	0	9	5	2
Other (17)	68	26	27	17
Total	**145**	**147**	**100**	**54**
Yearlings				
Unspecified trauma	1	13	12	1
Unknown	16	11	10	5
Tuberculosis	0	16	3	3
Other (10)	6	14	13	7
Total	**23**	**54**	**38**	**16**
Adults				
Unspecified trauma	6	11	13	7
Unknown	7	8	11	7
Tuberculosis	1	102	5	5
Endometritis	3	3	4	3
Dystocia	2	4	4	4
Kidney failure	3	3	4	4

Pneumonia	2	5	4	4
Other	29	24	27	15
Total	**53**	**160**	**72**	**49**

a - May 1, 1999 - April 30, 2000

b - The number of incidents in which a veterinarian was consulted for diagnosis or treatment strategies.

Table 3. Handling specific injury and proportional[a] mortality due to handling for elk calves, yearlings, and adults.

	Calves	Yearling Heifers	Yearling Bulls	Adult Cows	Adult Bulls	Total
Injuries						
Number of farms	201	166	161	198	181	227
Number at risk	3008	1147	900	3365	2205	10625
Number injured	28	12	17	25	35	117
Crude % injured	0.9 [b]	1.0	2.1 [b,c]	0.7 [c]	1.6	1.2
Mean % injured	2.2	1.1	3.3	1.3	1.6	2.2
Range	0.0-100.0	0.0-50.0	0.0-100.0	0.0-33.3	0.0-50.0	0.0-100.0
Mortality						
Number of dead	5	2	0	2	3	12
Crude % mortality	0.2	0.2	0	0.1	0.1	0.1
Mean % mortality	0.8	0.4	0	0.1	0.1	0.7
Range	0.0-100.0	0.0-50.0	0	0.0-14.3	0.0-7.7	0.0-100.0
Case fatality rate						
Crude case fatality %	17.2	16.7	0	8.0	8.6	9.8
Mean case fatality %	18.8	25	0	9.1	11.9	14.3
Range	0.0-100.0	0.0-100.0	0	0.0-100.0	0.0-100.0	0.0-100.0

a. Proportions are expressed as the percent of all elk that were injured or died following a single handling event during the period May 1, 1999 - April 30, 2000..

b, c - statistically significant difference between groups ($P<0.05$)

Table 4. Primary diagnosis of submissions[a] for all ages of elk to pathology laboratories.

Disease	Cases				
No diagnosis	144	Liver disease	33	Stillborn	14
Trauma	119	Parasitism	28	Neoplasia	13
Pneumonia	88	Liver flukes	25	Johne's disease	13
Enteritis/diarrhea	70	Abortion	23	Peritonitis	13
Emaciation	61	Grain overload	18	Meningitis	13
Septicemia	55	Encephalitis	17	Copper Deficiency	10
Abscess	40	Dystocia	16	Other	212
Kidney disease	37	Cardiac disease	15	**Total Submissions**	**1077**

a - 1990 - 2000

Table 5. Primary diagnosis of elk submissions[a] to pathology laboratories by age group[b].

Disease	Cases				
Less than 30 days of age[c]					
Enteritis/diarrhea	48	Trauma	10	Enteritis, necrotic	3
Septicemia	29	Dystocia	7	Myopathy	3
No diagnosis	28	Liver disease	7	Non viable neonate	3
Pneumonia	18	Kidney disease	6	Abomasitis	2
Still born	14	Omphalophlebitis	5	Other (23)	25
Emaciation	13	Cardiac disease	3	**Total submissions**	**224**
30 to 365 days of age					
Pneumonia	20	Abscess	7	Cardiac disease	2
No Diagnosis	15	Enteritis/diarrhea	5	Listeriosis	2
Trauma	13	Meningitis	5	Coccidiosis	2
Parasitism	10	Johne's	4	Copper deficiency	2
Emaciation	9	Grain overload	4	Other (27)	35
Septicemia	7	Encephalitis	3	**Total Submissions**	**145**
Older than 1 year of age					
Trauma	77	Encephalitis	13	Cardiac disease	7
No Diagnosis	70	Grain overload	13	Copper Deficiency	7
Pneumonia	35	Neoplasia	12	Capture myopathy	6
Kidney disease	31	Dystocia	9	Liver flukes	6
Emaciation	23	Liver flukes	9	Arthritis	5
Abscess	19	Peritonitis	9	Locoweed poisoning	5
Liver disease	16	Johne's	8	Other (37)	71
Enteritis/diarrhea	14	Septicemia	8	**Total submissions**	**473**

a - 1990 - 2000

b - excluding cases with unrecorded age (n=206)

c - including animals < 24 h old but not less than term fetuses (n=29)

A cross-sectional study of reproductive indices and fawn mortality in farmed white-tailed deer.

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Abstract

Data were obtained from a questionnaire administered to a random sample of Canadian and United States white-tailed deer farmers. Reproductive indices and survival of fawns from birth until 1 year of age were examined. Major factors in limiting herd increase were a low reproductive rate (88 fawns per 100 does exposed to bucks) and a 30% mortality of fawns from birth until 1 year of age. The latter figure differs from reported mortality rates in fallow deer and red deer / wapiti. The unacceptably high neonatal mortality on WTD farms was determined to be as important to herd productivity as failure to produce a live fawn. Industry wide, "benchmark" estimates of reproductive performance, mortality rates, and productivity are provided, allowing farmers to compare their herds against these "benchmarks" to identify areas needing improvement.

Introduction

No data concerning the productivity of white-tailed deer (WTD) (*Odocoileus virginianus*) under farming conditions appears to be available, in contrast to other species of farmed deer, particularly red deer and wapiti (*Cervus elaphus*) and fallow deer in which indices are available (1-5).

The precise number of farmers of WTD is not known, but Jacobson (2002) has reported that there are 4011 such farms in 15 US states and 6 Canadian provinces. The Canadian figures (537 farms) reported by Jacobson (6) tally closely with those of Haigh (7) (536 farms) whose data were derived from information provided by government staff using compulsory registration figures.

Measurements of reproductive performance, mortality rates, and productivity were obtained on a random sample of Canadian and United States WTD farms for the 1999-2000 production year in an attempt to provide "benchmark" estimates of these indices. The data presented here are derived from a survey designed to provide information on productivity and diseases of cervids farmed in North America.

Materials and methods

After consultation with departmental colleagues, the questionnaire was pretested at 2 industry conventions: Prototype questionnaires were administered to cervid farmers who were later interviewed and asked if they understood each question and whether they could provide the data requested of them. Consequently, a set of questions was produced that were considered to be well understood by cervid farmers and to have potential to capture the data required for the study. The questionnaire was then mailed to selected North American producers; to ensure confidentiality, only the name of the state or province where respondents farmed was requested.

A random sample of 340 WTD producers was selected from a pooled database of 1424 producers assembled from national, provincial, state, and regional deer farming association membership lists. Producers were grouped and sampled proportionately according to nationality. The sample size was selected to detect a disease with a herd level prevalence in the sampling frame of 2% with 95% confidence if 50% of the questionnaires were returned.

Questionnaires were designed to capture data specific to rates and proportions of productivity and reproductive performance on WTD farms during the study period. Since the period of the study was 1 production year, reproductive rates were calculated for adult and primiparous does as percentages over a 1 year risk period.

The format of the questionnaire followed Dillman's recommendations for maximum response to postal questionnaires, which involves the sending of 4 carefully timed mailings (8). To maximize the response rate, respondents were made eligible for a lottery draw for 5L of an anthelmintic (Cydectin ,Wyeth Animal Health, Guelph, Ontario). Included with the questionnaire was an explanatory letter introducing the survey and emphasizing the benefits of the study, a

74 lottery entry form, and a stamped self-addressed return envelope. Postcard reminders were sent
75 out to all producers 2 and 4 wk later. After approximately 6 wk, a 2nd identical questionnaire
76 package was mailed to nonresponders and postcard reminders were mailed to them 2 and 4 wk
77 later.

78 To ensure confidentiality, responses were immediately coded after receipt and entered
79 into a database (Microsoft Access, Microsoft Corporation, Redmond, WA) with no association
80 between answers and respondents. Database entries were checked twice against questionnaires
81 for their accuracy, and the internal validity of the database was assessed by comparing the
82 answers with check questions. Database errors resulting from incorrect data entry were corrected
83 in the database, but questionnaires with inconsistent answers were eliminated from the analysis.

84 Reproductive and productivity rates (proportions) were based on 1 age cohort and
85 calculated over 1 production cycle. For instance, the fawning rate (proportion) for does was
86 expressed as the proportion of all does exposed to breeding that produced a fawn, on farm at
87 fawning time. Cohort specific morbidity and mortality rates for calves born in 2000 were not
88 based on 1 year periods; rather they were based on specific time periods of risk. For example,
89 neonatal mortality rates were calculated as a proportion of those fawns born during the 2000
90 fawning season that died within 1 month after birth.

91 Reproductive performance was expressed as a measure of a doe being able breed, deliver
92 a live fawn, and keep it alive until it reached reproductive age (1y). Reproduction losses were
93 defined for the period from exposure of does to breeding until the time when the fawns produced
94 by that breeding reached 1 y of age. The percentage of total reproduction losses for WTD due to
95 either failure of does to deliver a live fawn or fawn mortality was recorded. Total reproduction
96 loss included all does that were exposed to breeding but failed to produce a fawn plus all fawn

97 mortalities from birth to 1 y of age.

98 Dystocias were defined as does that were unable to deliver their fawn(s) without
99 intervention.

100 Fawning percent was defined as the proportion of does present at breeding that produced a
101 live fawn. Live fawns were fawns that survived birth and were alive for at least 24 h after birth.

102 To determine which factor caused more reproductive loss, the total reproductive loss was
103 separated to show the proportion of does exposed to breeding that failed to produce a live fawn (a
104 traditional measure of reproductive performance) compared with the proportion of fawns that
105 were born alive that died within 1 y.

106 Fawn mortalities were recorded for 5 specific risk periods after birth in adult and
107 primiparous does: birth to 24 h, 24 h to July 1st (most fawning occurs late May and early June),
108 July1 to weaning, weaning period, and post weaning to 1y.
109

Results

One hundred and two farmers responded to the survey. The response rate for the deer questionnaire was 30.0 % overall (25.4 % of US and 33.3 % of Canadian deer farmers). The total number of deer included in responses was 4998 and the average herd size was 49 deer. The number of responses varied among questions. Among the 1819 adult and primiparous does that were exposed to bucks, 314 were no longer on farm. From the remaining 1505 does, 1603 fawns were born for a fawning rate of 106%, or 88% for all does exposed to breeding. The productivity of white-tailed deer from breeding to fawning is shown in Table 1. The reproductive losses from birth to one year of age are shown in Table 2. Table 3 shows the period specific mortality of white-tailed deer fawns from birth to 1 y of age.

Fawning

Adult does had slightly higher fawning rates (80 farms, crude rate 91.9%, range 0-100%) than did primiparous does (65 farms, crude rate 83.7%, range 0-100%).

Sixty-nine farmers (58%) reported that at least 1 doe had failed to produce a live fawn.

Dystocias

Of a total of 89 farms, 12% reported does having dystocias (up to 50% of does on some farms). The overall crude rate of dystocias was 1.1%. Of these dystocias, 60% on 11 reporting farms were associated with twin fawning.

Abandonment

Both adult and primiparous does abandoned fawns. Of 79 farms responding about adult does, 7.6% reported abandonment. On 62 farms, 4.8% reported primiparous does abandoning fawns. In a total of 86 farms, 9.3% reported fawn abandonment.

133 *Fawn mortality*.

134 A total of 1603 fawns (excluding aborted and abandoned fawns) were born on 85 farms.

135 Table 3 summarizes the period specific fawn mortality. The highest percentage of fawn deaths

136 (14.1 % of calves at risk) occurred in calves surviving 24h, but dying before July 1st.

Discussion

White-tailed deer doe fawns are capable of breeding at less than 1y and, under good nutritional conditions, may, on average, produce as many as 1.18 fawns per doe (9). However, most WTD farmers do not expose fawns to a buck and are careful to separate buck and doe fawns at weaning time, as buck fawns may also be fertile. It is not uncommon for WTD does to produce twins. In wild populations, fecundity of prime age (3-7 y of age) and 2-year-old does on moderate to high nutritional planes ranges from 1.53 to 1.85 fawns per doe. However fecundity in 2-year-old does may drop to 0.5 fawns per doe on low nutritional planes (9).

Our results indicate that the WTD farmers surveyed have not been able to capitalize on the reported fecundity rates seen in wild deer and reported by a few WTD farmers; some clients of the WCVM practice where up to 200 fawns per 100 does have been reported (Friesen, personal communication). When a fawning rate of 88% of exposed does is compared with the higher figures published for wild WTD, it is clear that a substantial productivity loss occurs before fawning. Reproductive losses, including failure to breed, failure to conceive, and fetal resorption, need to be investigated.

Our data on the range of reproductive losses after fawning (0-100%, Table 2) highlight a wide variability in reproductive efficiency and loss between farms. Similar observations have been made among red deer and fallow deer farms in New Zealand and Australia (1-3).

In red deer enterprises, the reproductive performance of females, particularly young females, is recognized as a major factor in productivity and, ultimately, economic viability (2,4). Calving rates approaching 90% are reported for both red deer and wapiti, with weaning rates lower by 10% or less (3,10).

In a study on 15 New Zealand deer farms, involving 2700 hinds, the percentage of

yearling and adult hinds conceiving before May (autumn in the southern hemisphere) ranged from 8.3% to 95.0% and from 77.6% to 98.4%, respectively, among farms. Overall, the proportion of yearling and adult hinds not conceiving was 15.3% and 3.2%, respectively. Less than 1% of hinds of either age group suffered losses in utero. Calf survival rates to weaning were 84.1% in yearlings and 91.6% in adult hinds. However, when precalving losses (including failure to conceive) were factored in, the reproductive efficiency was 70% and 83.6%, respectively (2).

Unfortunately we did not have access to ultrasonographic information on conception rates of WTD. Had it been available, a much more accurate index of prepartum breeding information would have been available, but it would not have altered the postpartum data. Ultrasonographic information has been obtained for red deer (2), but the authors are not aware of any such information for WTD

On wapiti farms, calving rates of 81% and 96 % for 2-year-old and adult hinds, respectively, with an overall herd average of 93 % have been reported (3). Weaning rates (88% overall) in the same study were 73 % for 2-year-old and 91% for adult hinds. Dystocia accounted for two-thirds of the total calf mortalities. Overall calf mortality was 5.2 %, with a trend (P = 0.07) for 2-year-olds to experience higher calf mortalities (9.5 %) than adult hinds (4.4 %).

Reproductive wastage on fallow deer farms, excluding failure to conceive or prenatal losses, has been reported to be between 19 % and 20 %, figures that the authors considered to be unacceptably high (5,10). Twinning in fallow deer is rare and conception and fawning rates are commonly above 95% (1). A major factor in fawn mortality of fallow is the weight of the fawns. Sixty to seventy percent of newborn fawns less than 3.0 kg in weight are nonviable (1). The weights of WTD fawns born or abandoned were not available to us. Studies of fallow deer in the 1980s revealed that perinatal and early postnatal fawn mortality accounted for the majority of lost

reproductive potential, 11% to 19% of fawns born. In particular, fawn losses due to "nonviability syndrome" (low birth weight), starvation/dehydration (mismothering), dystocia, misadventure, and infectious agents were prevalent at varying rates across farms (1).

The magnitude of traditional reproductive failure (failing to breed plus failing to produce a live fawn) is only a matter of conjecture, but if the figures of Verme and Ullrey (9) are used, it may be that the number of fawns born to farmed does is little more than 50% of the potential.

We used the term reproductive loss in order to highlight to the magnitude of postpartum fawn mortality in a way that relates to some overall measure of a breeding herd's ability to produce and raise offspring to breeding age. In contrast to red deer and wapiti, neonatal mortality on WTD farms was probably just as important to herd productivity as failure to produce a live fawn. A loss of 29.8% of live fawns born is higher than for any reported for other commonly farmed deer (red deer, wapiti, and fallow deer). Even when weaning and postweaning figures are removed (which allows direct comparison with reports in those species), the losses are unacceptably high (24.8% of fawns born).

Industry wide measurements of reproductive performance, mortality rates, and productivity provide "benchmark" estimates of these indices. Farmers can compare their own herds against these "benchmarks" to identify areas to improve efficiency. Scientists can identify management areas that need improving and thereby help to develop management strategies that will enhance the overall performance of cervid farms. Data on the causes of loss obtained in this survey are described elsewhere (12).

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12. Jerry Haigh JC, Berezowski J, Woodbury MR. A cross sectional study of the causes of morbidity and mortality in farmed white-tailed deer. Submitted to CVJ.

240 Table 1. Production losses of white-tailed deer from breeding to fawning.

241

	Number	Percentage
Does bred (89 farms)[a]	1819	
Bred, no fawn seen	198	11.0
Does reported aborting	9	0.5
Does abandoning fawns	9	0.5

242

243 Table2. Reproductive losses after fawning in farmed white-tailed deer

244

Number of farms reporting fawn mortality[a]	69
Percent of all farms reporting fawn mortality	81.2%
Total number of fawn deaths	478
Range of the percent of loss among all farms that was due to fawn mortality	0-100%

245

246 a. number of responders varied among questions

247 Table 3. Period specific mortality of white-tailed deer fawns from birth to 1 y of age.

248

	Period				
	<24h[a]	before July 1[b]	July 1 to weaning[c]	Weaning[d]	Weaning to 1 y[e]
Number of farms[f]	85	85	85	85	85
Number of calves at risk	1603	1566	1346	1206	1181
Number of mortalities	37	220	140	25	56
Crude % mortality	2.3	14.1	10.4	2.1	4.6
Range (%)	0.0-50.0	0.0-60.0	0.0-72.7	0.0 - 50.0	0.0-100.0
% of total calf mortality	7.8	46.1	29.2	5.2	11.7

249

250 a. calves born alive that died within 24h of birth.

251 b. calves born alive that died before July 1st.

252 c. calves alive at July 1st that died before weaning.

253 d. calves alive at weaning that died within one month of weaning.

254 e. calves alive one month post weaning that died by one year of age.

255 f. number of responders varied among questions

A cross sectional study of the causes of morbidity and mortality in farmed White-tailed deer.

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Abstract

Two questionnaires were designed and administered. The first was to a random sample of 340 Canadian and United States of America (USA) farmers of white-tailed deer (WTD) (*Odocoileus virginianus*). The second was a 10 year retrospective survey of deer submissions to veterinary diagnostic pathology laboratories in Canada and the USA was conducted. One year rates of mortality, and common causes of morbidity and mortality for the deer are reported. The primary diagnosis for each record was used to classify diseases into categories such as parasitic, infectious, toxicological, and neoplastic. Submissions were further classified according to the anatomical location, the pathological change, and the etiology associated with each lesion. Trauma was the most important reported cause of farmed WTD mortality, and necrobacillosis was a major cause of morbidity & mortality, especially in fawns.

Introduction

The purpose of this project was to report the causes of sickness and mortality in farmed WTD in Canada and the USA and to estimate the age and sex specific mortality rates, reproductive performance, productivity, and effect of mortality on productivity of farmed WTD for the 1999-2000 production year. The precise number of farmers of WTD is not known, but Jacobson (1) has reported that there are 4,011 such farms in 15 US states and 6 Canadian provinces. The Canadian figures (537 farms) reported by Jacobson (1) tally closely with those reported by Haigh (2) (536 farms) whose data are derived from information provided by government staff who used compulsory registration figures.

Farmers were asked to name diseases which caused sickness or mortality on their farms both during and before the period of the study. For various reasons, including farmers failing to have sick animals or mortalities examined by veterinarians, it was considered that farmers might be unable to accurately report causes of sickness and mortality. In order to more accurately report specific causes of mortality in farmed deer, a 10 year survey of submissions to veterinary diagnostic pathology laboratories in Canada and the Western United States was conducted. Although it is recognized that surveys of submissions to diagnostic pathology laboratories are not representative of all causes of mortality, it was felt that the combination of a farmer and a laboratory survey would provide a more complete report of causes of mortality, than either survey alone.

Most of the existing information on diseases of deer has been generated in publications about red deer and wapiti (3,4,5,6,7). Some publications about fallow deer diseases are also

53 available (8,9,10,11,12). The most comprehensive source of information about diseases of WTD
54 deals primarily with free-ranging animals (13). There is little material available about diseases of
55 farmed WTD. In his 1877 book Caton (14) refers to diseases of captive deer and gives a graphic
56 description of what was probably necrobcillosis . Diseases of captive WTD are also discussed in
57 a wider paper that covers farmed cervids in Michigan (15).

Materials and Methods

This study was designed in two parts, a producer survey and a laboratory survey. Each section of the study was designed to gather different types of observational data. Farmer questionnaires gathered data about morbidity and mortality from all causes. Productivity and reproductive performance statistics on WTD farms have been reported elsewhere (17). Farmer questionnaires were designed to capture data specific to rates and proportions. Since the period of the study was one production year, morbidity and mortality rates were calculated for adults and yearlings as percentages over a one year risk period.

The questionnaires asked farmers to name diseases that caused sickness and death among their WTD during the period of the study. From these data the relative importance of various causes of disease or disease syndromes were estimated for the study period. Farmers were also asked to provide the names of any diseases or disease syndromes they experienced in their WTD during previous years. Data from these questions were used to estimate the commonality of disease causes and disease syndromes.

Producer survey

This study was designed in two parts, a producer survey and a laboratory survey. Each section of the study was designed to gather different types of observational data. Farmer questionnaires gathered data about morbidity and mortality from all causes. Productivity and reproductive performance statistics on WTD farms have been reported elsewhere (Haigh et al, **second submission herewith**). Farmer questionnaires were designed to capture data specific to rates and proportions. Since the period of the study was one production year,

morbidity and mortality rates were calculated for adults and yearlings as percentages over a one year risk period.

The questionnaires asked farmers to name diseases that caused sickness and death among their WTD during the period of the study. From these data the relative importance of various causes of disease or disease syndromes were estimated for the study period. Farmers were also asked to provide the names of any diseases or disease syndromes they experienced in their WTD during previous years. Data from these questions were used to estimate the commonality of disease causes and disease syndromes.

Producer survey

A sub-set of 35 questions from the questionaire was designed to gather data about the rates of mortality and morbidity in farmed deer. After pretesting on producers at two industry conventions to ensure that they understood the questions and could provide the data requested of them, the questionaire was mailed to North American producers. To ensure confidentiality only the name of the state or province where respondents farmed was requested.

A random sample of 340 WTD producers was selected as described in Haigh et al (accompanying submission). The format of the questionnaire followed Dillman's recommendations for maximum response to postal questionnaires (4).

The at-risk study population was stratified according to age and sex, and mortality rates were calculated for each age and sex class over the one year period of the study. Producers were asked to name diseases which caused sickness or mortality on their farms during and before the period of the study. Morbidity and mortality rates were calculated for adults and yearlings over

the 1999-2000 production year and expressed as percentages. Cohort specific morbidity and mortality rates for calves born in 2000 were not based on one year periods; rather they were based on specific time periods of risk. For example, neonatal mortality rates were calculated as a proportion of those fawns born during the 2000 fawning season, that died within one month after birth.

Pathology Laboratory Survey

Forty two veterinary diagnostic pathology laboratories in the US and Canada were contacted and asked to participate in the study. Of those laboratories willing to participate, 8 were selected for inclusion based on the number of deer laboratory submissions they received over the period from 1990 to 2000 and their ability to extract useful information from their records. These included laboratories form Alberta, British Columbia, Colorado, Minnesota, North Dakota, Saskatchewan and South Dakota. Visits were made to three laboratories and detailed information was generously provided by the others.

Submissions which included more than one dead animal were entered as a single record and each submission was considered one disease outbreak without regard to size. Data was extracted from each record and coded into a Microsoft Access database. To maintain client confidentiality, individual pathology submissions were identified only by an ID number. Keystone information stored for each record included submission date, age, sex, species, and primary cause of mortality. The primary diagnosis for each record was used to classify records into disease categories such as parasitic, infectious, toxicological, neoplastic diseases, etc. In addition, 3 pathological lesions were recorded for each submission based on the anatomical

location, the pathological change, and the etiology associated with each lesion. Database entries were checked twice against the original records for the accuracy of each entry.

Results

Farmer responses

One hundred and two farmers responded to the survey. The response rate for the deer questionnaire was 30.0% overall, with 25.4 %of US deer farmers and 33.3% of Canadian deer farmers responding. The total number of deer included in responses about morbidity and mortality was 5035 and the average herd size was 49 deer.

Mortality and morbidity rates among various cohorts of deer are shown in table 1. The specific causes of death and disease are listed in table 2 and 3. Table 2 shows combined data for all deer, table 3 being specific to fawns. In the combined data set (table 2) animal handling was the greatest cause of problems. In table 4 the breakdown of handling related injuries according to age cohort is shown. All classes of deer are represented in this table, with yearling bucks having the highest percentage of injuries (7.6% of handled yearlings were injured).

Pathology laboratory responses

A total of 505 white-tailed deer were submitted for pathology diagnosis. Of these, 194 were female, 153 were male and in 158 cases the sex was not recorded. There were four fetuses. The ages of other deer were as follows: <24 hr, 5 cases / 24 hr-7 d, 8 cases / 8 days –30 days, 36 cases / 31 days – 1 yr, 97 cases / 1-2 yr, 53 cases, >2yr 161 cases. In 141 instances ages of submitted deer were not recorded.

The primary pathologic diagnoses are listed in table 5.

Among the 44 etiologic agents isolated in cases of pneumonia there were 10 cases in

which *Arcanobacterium pyogenes* was found. Others included *P. haemolytica* (4 cases) *E. coli* (3), *P. multocida* (2), *Aspergillus spp.* (1) and *F. necrophorum* (1). Foreign bodies were found in 2 cases, unspecified bacteria in three others, and in 18 cases no agent was recorded.

Twenty cases of parasitism due to a recognized agent were reported to have been responsible for mortality. Of these, eight were described as coccidiosis, two as liver fluke (*Fascioloides magna*), four as strongyle infections, three as Trichostrongylosis and in one case each the agents were named as *Strongyloides spp., Trichuris spp.,* and *Parelaphostrongylus tenuis.*

Other than the parasitic agents that affected the gastrointestinal tract the following bacterial pathogens were implicated in cases of enteritis and diarrhea. *E. coli* (4 cases), *Clostridium perfringens* (2), *Salmonella spp.* (2), *Yersinia* spp. (1). Viruses reported in cases of enteritis and diarrhea included Rotavirus (4) Adenovirus (1) and Parvovirus (1).

A total of 32 abscesses were diagnosed at necropsy (21 as primary diagnoses). In 17 of these no bacteria were isolated. The remainder were classed as follows: *F. necrophorum* (11), *A. pyognes* (2), *Yersinia spp.* (1), *Clostridium spp.* (1).

There were 44 reports in which pneumonia was the primary diagnosis. No pathogen was named in 18 of these. The pathogens involved were as follows: *A. pyogenes* (10 cases), *P. haemolytica* (4), *E. coli* (3), *P. multocida* (2), *Aspergillus* spp., unspecified *Pasteurella*, *F. necrophorum* (1 each). In addition unspecified bacteria were listed in 2 cases, and foreign bodies were recorded twice.

Discussion

It has been well recognized that data generated by surveys of pathology laboratory submissions may suffer bias and be unrepresentative of the general population. Since farmers may not have postmortem examinations performed on all mortalities, the proportions of diseases measured by pathology surveys are often not the same as the proportions of disease occurring within the general population. For the purposes of this study, surveying pathology laboratories provided a broader database of disease etiologies, and provided some support for the validity of disease etiologies reported by farmers when they responded to the questionnaires.

Surveys of pathology submissions, however provide valuable information to farmers, veterinarians and diagnostic pathologists. Although pathology survey results may not be completely accurate, they do provide rough estimates of the importance of various diseases as causes of mortality. Especially for farmed deer species such as WTD, in which published information about etiologies and occurrence of disease is sparse, pathology surveys identify, report, and alert farmers, veterinarians, and pathologists to disease etiologies which they may have been previously unaware. Focusing attention on diseases which have been previously unreported or which may be newly emerging within cervid populations allows interested groups to target efforts at prevention or control of these diseases at an early stage.

Trauma is recognized as a major cause of both morbidity and mortality in famed wapiti and red deer (5,18,19,20,21). In a survey of 191 cervid farmers (5493 animals, of which 90.5% were WTD) in Michigan, a one year period prevalence rate of 1.9% and a case fatality rate of 52% of injured deer were recorded (15). Our data (Table 2) show that almost a quarter of all

deaths reported by farmers were due to trauma. Most of these events occurred during handling (Table 4), and that between 23% and 49% of deer injured during these procedures went on to die. Trauma was the most common primary diagnosis at pathology laboratories

It is likely that the design of handling systems and inappropriate human actions made a significant contribution to these injuries. On one WCVM client farm where stockmanship was of a high order and a handling system had been designed with low-light sheds and a padded chute (22), only one handling related death occurred over a period of ten years. Many hundreds of handling events took place during this period (Friesen pers. comm.). It is incumbent upon WTD farmers to ensure that good handling systems are in place, and properly trained individuals are working the animals, because much of the responsibility for successful (and unsuccessful) outcomes rests with the humans involved (23). Good handling will increase profit margins by reducing both injuries and stress related disease.

When data for all ages of deer were combined the second most common cause of death and morbidity reported by farmers was necrobacillosis. The data indicate that fawns are particularly susceptible. When unknown causes of death and morbidity are removed from calculations this condition alone caused 38% of deaths, and 56% of sickness in fawns.

Necrobacillosis is well known in both wild and captive deer populations, and is a common disease condition in numerous other species (5,7,10,11,24). The disease has been reported to be of particular significance in farmed WTD (25). What is probably the first report of necrobacillosis in WTD appeared in Caton's 1877 book The Antelope and Deer of North America. He states, "I have lost many Virginia deer with a swelling under the lower jaw. It

commences two or three inches back of the chin, and finally swells out so as to involve the whole head below the eyes; sometimes it gathers in a sac of half an ounce of pus-like matter, one of which I opened, but the deer died." He later goes on to say that if he detects it early enough and opens the lesion the "deer gets well at once." (14). A useful review of the history of this condition, and its occurrence in WTD is provided in Wobeser et al (26).

It is likely that farmers of WTD have become all too familiar with necrobacillosis, and this would account for the apparently low incidence of its diagnosis in pathology laboratories, as most farmers will recognize it and choose not to submit carcasses or samples that will cost money.

Tuberculosis and Chronic Wasting Disease, two diseases of importance to WTD in North America, were not reported in the survey. The former was been documented in farmed deer in Michigan in 1997 (27), and the latter had not been reported in farmed WTD at the time that the survey was conducted. The number of farms on which either of these conditions has been reported in WTD is small, and as our survey return rate of 30% of 340 farms initially approached was only a fraction of the estimated over 4000 WTD farms (>71,000 animals) in Canada and the U.S.A. we had less than a 2.5% chance of receiving reports of either condition.

We discarded data when questions asked in different ways, but seeking the same information, gave inconsistent results. It is still possible that some of the data from both parts of the survey did not provide accurate diagnoses. Recall bias and diagnostic errors may have skewed the information. Nonetheless we feel that the survey provided a useful snapshot of WTD morbidity and mortality. If injuries could be reduced by improved handling methods, and if

necrobacillosis could be better controlled through improved management and possible use of vaccines, then profitability would rise and welfare concerns would be much reduced.

Data from both sets of questions about causes of disease provides a list of diseases ranked by importance, that can be used by farmers and veterinarians as a list of "most likely causes" when they are faced with disease outbreaks on WTD deer farms. This list will allow farmers and veterinarians to be more selective of diagnostic tests and treatment programs when managing disease outbreaks. Making this list available to researchers studying cervid diseases will allow them to focus their efforts on diseases which are most common or economically significant on WTD farms.

Acknowledgements

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303
304 Table 1 One year mortality rates for farmed white tailed deer
305

	Farms	Yearling male	Yearling female	Adult male	Adult female
No. of farms	69	77	72	86	84
Deer at risk	1603	586	505	998	1343
No. dead	478	37	18	53	56
% mortality	29.8	6.5	3.6	5.3	4.2
Range (%)	0 –100	0 –100	0 –100	0 –100	0 –50

306

307 Table 2 Injuries and deaths related to handling in farmed white-tailed deer as reported by farmers.
308 All figures reported from a single handling event.
309

	Fawns	Yearling male	Yearling female	Adult male	Adult female	Total
No. of farms	77	60	56	67	69	
Deer at risk	1574	473	442	710	1089	4288
No. injured	41	36	17	40	50	184
% injured	2.6	7.6	3.8	5.6	4.6	4.3
Range %	0 –100	0 –60	0 -100	0 -100	0 –100	
% died acutely	3.2	3.6	0.2	0.9	0.9	
Range %	0 –100	0 –43.5	0 –10	0 –20.0	0 -16.7	
No. died following injury	41	37	17	42	50	187
% Case fatality rate	48.8	48.6	23.5	40.5	24.0	
Range %	0 –100	0 100	0 66.7	0 –100	0 –100	
No. died of CM*	23	18	0	17	12	70
% died of CM	8.7	5.6		11.8	41.7	
Range %	0 -50	0 100		0 –50.0	0 -100	

310
311 * CM = capture myopathy

312 Table 3 One year farmer reported causes of morbidity and mortality for white-tailed deer adults, yearlings and fawns combined. Included are
313 the number of sick deer, the number of dead deer, the number of outbreaks of each disease and the number of farms that consulted a
314 veterinarian to diagnose or manage each disease (Vet).
315

Disease Name	Total Sick	Fawns sick	Yearlings sick	Adults sick	Number Dead	Fawns dead	Yearlings dead	Adults dead	Number of Reports	Vet
Trauma	12	4	2	6	118	56	22	30	58	19
Unknown	54	34	6	14	114	76	19	14	56	19
Necrobacillosis/Lump jaw	112	102	1	9	107	103	NR	4	13	7
Pneumonia	22	19	0	3	38	30	1	7	17	13
Salmonellosis	28	28	NR	NR	31	28	1	2	3	3
Exposure	6	5	1	NR	19	19	NR	NR	4	1
Calf Scours	8	8	NR	NR	8	8	NR	NR	3	1
Grain Overload	5	4	1	1	7	6	1	1	4	3
Predation	0	0	NR	NR	7	2	NR	5	3	0
Abscess	10	NR	NR	10	6	NR	NR	6	1	1
Coccidiosis	4	2	NR	2	6	4	NR	2	3	2
Others*	20	11	7	3	37	15	8	30	31	22
Total	**281**	**217**	**18**	**48**	**498**	**347**	**52**	**101**	**196**	**91**

316 NR = none reported
317 * others include: Abandoned fawn, Abomasal ulcer, Abortion, Bloat, Capture myopathy, Choke, Congenital anomaly, Cryptosporidiosis,

318 Diarrhea, E. coli, Fescue poisoning, Foot rot, Drowning, Dam no milk, Drug reaction, Intestinal accident, Lightning strike, Listeriosis,
319 Neoplasia, Old age, Parasites, Unspecified infection.
320